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Study and Effect of Orientation two Room of Buildings Located in Ghardaïa, Algeria.

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Abstract

Thermal comfort plays a major factor in building infrastructure sector. It has a big impact on building interior temperature as well as on energy balance and environment. In the current paper the influence of thermal isolation, building orientation and thermal inertia of building envelop on interior ambient temperatures have been studied. To meet our objective, a methodological procedure has been followed. It consists of elaboration of computing program written in MATLAB code to simulate the proposed mathematical model. The main objective of the proposed mathematical proposed model is to compute different delivered temperatures under real climatic and environment conditions. Confrontation of the results found through simulation with those found experimentally shows a clear consistence. Thus the theoretical model is experimentally validated. It can be concluded that: The most effective measure to achieve a better results is thermal insulation. The orientation of thermally isolated building doesn't have a considerable impact on interior temperature. Thermal inertia of buildings may thus generate thermal comfort. It was revealed that an adequate use of stone thermal inertia is essential to achieve a better building thermal comfort.

Key Words: Temperature, Thermal Insulation, Orientation, Thermal Comfort, Buildings,Numerical Simulation;

1. Introduction

The seventies housing crisis had inspired the interest in bioclimatic architecture. As the most nowadays built houses are intact and combustible energy reserves are exhausted. Decline towards the bioclimatic architecture becomes an issue. This principle of architecture requires first an adequate choice of house location and orientation and then warmth and cold requirements. Over the last years the exigencies of

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thermal comfort have been significantly improved. In parallel to this improvement numerical methods that predict the thermal behavior of the housing envelop have been elaborated. These models allow the evaluation of internal temperatures in terms of thermal comfort to be achieved [1, 2].However, it is not appropriate to consider air conditioning, or heating systems without tacking into account the outside temperature fluctuations, building orientations, and the strength of the insulating material to be used, internal charges and construction materials used… Classical methods used to compute the energy consumption and energy demand [3-4] are not adequate since the effect of interaction of different basic building constituents and the suggested solution are not dealt with [5].

2. Presentation of the ghardaïa saharan oasis

The case study of this research is the agglomeration of Ghardaïa situated in M'zab valley in northern part of Algerian Sahara, is situated at the south of capital (600 km)between 32° and 33°20° Northern latitude and 2°30° longitude East at an average altitude of 500m. The climate is hot and dry in summer, with a large temperatures swings, intense solar radiation, and strong winds. The winter is cold and moderately wet. , characterized by very low precipitations (160 mm/year), very high temperatures in summer and low temperatures in winter (frosty from December to mid-February). The climate is hot and dry in the summer with temperatures variation between a maximum of around 50 °C and a minimum of 20 °C, thus giving a large diurnal temperature swing. Winter temperatures vary between a maximum of 24 °C and a minimum of 0 °C. Its normal temperature in January is 10.4 °C, it is 36.3 °C in July. And the average annual range is about 12.2 ° amplitudes of monthly average temperatures. They are more moderate in winter than in summer (average 11° in winter cons 13.5° in summer). The monthly maximum amplitudes are larger in summer than in winter fluctuates around 20 °C. Solar radiation is intense throughout the year with a maximum of 700 Wm-2 in winter and 1000 Wm-2 in summer, measured on the horizontal surface. This Saharan climate result that insulation is necessary, some requirements have been identified by N. Fezzioui et al [6]. The Z. Chelghoum et al paper discusses adaptation for climate change through a local adaptation strategy at a variety of scales, showing how to manage high temperatures. The orientation effect of a non-air-conditioned building on its thermal performance has been analysed in terms of temperature index for hot-dry climates. The evaluation is derived from a series of computer simulations. This paper concentrates on analysing the effect of insulation and the orientation of the existing case of a typical house in Ghardaïa by finding the dynamic indoor air temperature for each orientation.

2.1. Descriptive of typical house plan

In Ghardaïa region, stones are the most used construction materials. It is has been used for centuries (since the foundation of the town at 1200 J) due to their availability and also due the lack of other construction materials such as wood (Vegetation are low due to the climate). A typical most commonly used construction in the region had been chosen. The figure 1 is a schematic outline of real apartment building situated whether at the ground or at the first floor of two storey building. The house has an area of 88 m2, wall heights are equal to 2.8 m while the other dimensions are shown in detail in Figure 1.

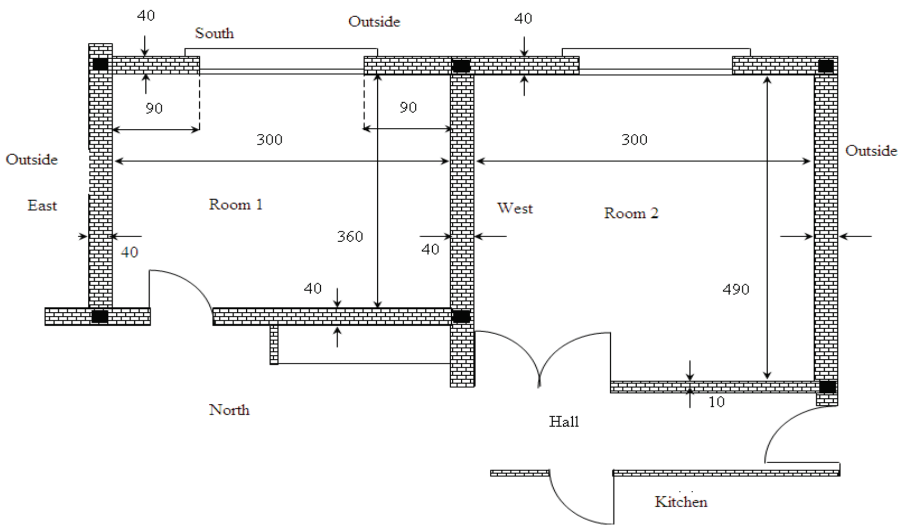

Fig1. Associated descriptive plan

This apartment includes the following elements:

- Building envelops or outer wall consisting of a heavy structure generally constituted of stones jointed and surrounded by two layers having thickness of 1.5 cm of mortar cement. The most inner face is coated with 1 cm thick plaster layer. The inner face of these walls may have a thermal insulating structure composed of an insulating polystyrene layer of thickness in the order of 6cm and an air layer of 1 cm.
- The inner walls (or splitting walls) whose sides are in contact only with the internal ambient are considered to be of heavy structure constructed of stones of 15 cm width jointed and surrounded by two mortar cement layer of 1.5cm thick and two layers of 1cm thick of plaster.
- The flooring is placed on plan ground to lodge the ground floor. The concrete of the flooring is directly poured on the ground thus minimizing losses. Floor tiles are inter-imposed, it is an end coating resisting to corrosion and chemical agents…
- The roof is composed of cement slabs and concrete slab made so that it handles the load and be economical. A roof sloping of 5° allowed water evacuation through several openings. Until now the flat roofs are considered as nest infiltration and as architectural solution.
- Windows and doors contribute significantly to the energetic balance. Their contribution however depends on several parameters as: local climate, orientation, frame, relative surface (window-flooring), and concealment performance during night and sunny days. In this case focus is made particularly on windows and doors dimensions and all are made of woods [5].

3. Incident solar irradiation estimation

Solar radiations play a primordial role in building heating. According to their trajectory, those radiations can be divided into two parts direct and diffused radiations. As solar radiation passes through the earth's atmosphere, some of it is absorbed or scattered by air molecules, water vapor, aerosols, and clouds. The solar radiation that passes through directly to the earth's surface is called direct solar radiation. The radiation that has been scattered out of the direct beam is called diffuse solar radiation. The direct component of sunlight and the diffuse component of skylight falling together on wall surfaces make up global solar radiation. In other words, the sum of both direct and diffused radiations is known as the global radiation.

We will be forced to choose an efficient numerical model to estimate the incident global irradiation on the walls. The chosen method is Capderou model that utilizes the atmospheric Linke turbidity factor in order to compute direct and diffuse components of solar irradiation. Absorption and diffusion caused by atmospherical particles are expressed in terms of the Linke turbidity factors. From these factors direct and diffuse irradiation are determined in case of clear sky model [5-6].

We are interested in determining the incident irradiation on the roof (horizontal) and the vertical surface of external walls. From Capderou model, the incident solar irradiation on an inclined plane is deduced from the incident solar irradiation on a horizontal plane. The use of directly experimental results provided by a station located in the site where studies are carried out is preferred because it allowed having more precise and better estimation of global irradiation on the walls; i.e. these values (solar irradiation on a horizontal plane obtained using Sun Tracker Station) are injected in Capderou model to simulate the global and diffuse irradiation falling upon a vertical plan. Sun-Tracker is a station with high precision comprises two parts: a fixed part consisting of an EKO type Pyranometer for measuring global solar irradiation received by a horizontal surface, a mobile part based on robotic system capable to follow the trajectory of the sun from sunrise to sunset.

Figure 2 presents instantaneous variations of solar irradiation incidents upon the roof and wall of the flat for different orientations. These values correspond to the days of August 01st under clear sky condition.

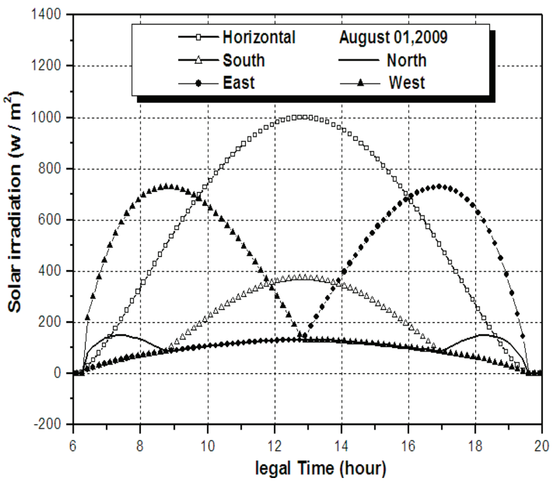

Fig2. Incident solar irradiation on walls,01 August 2009

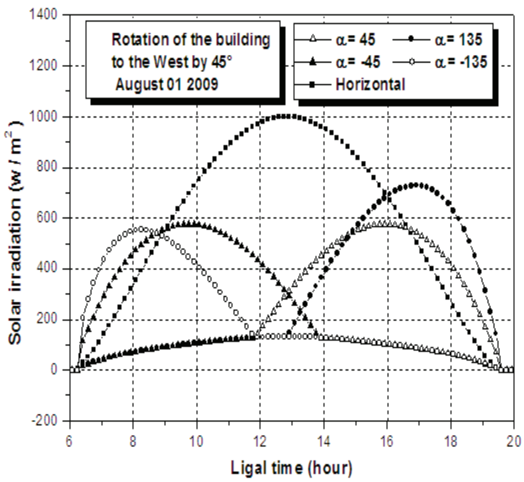

Fig3. Incident solar irradiation on walls, West rotation by 45°. 01 August 2009

Whereas figure 3 represents instantaneous variation of solar irradiation incident upon different surfaces of the flat for second day of June with the following orientations: South East (α = - 45°), South West (α = 45°), North East (α = 135°) and North West (α = - 135°)

4. Appropriate Thermal Study

4.1 Mathematical model

However, these models and even more the latter only concern heat exchanges. As consequence of this air stratification studies (wind infiltration influence, and water droplets diffusion in wall cavities…) are not considered in the current study. Variation of humidity factor and states changes is not taken into account either. In the current work it is the envelop which is exclusively studied.

To carry out this study few specific hypothesises are made:

- The flow through different walls layers is assumed to be unidirectional.
- The permanent regime would be established when the flow passes from layer to the next one.
- Temperature distribution (internal and external) on each wall surfaces is considered to be uniform.

Thus, the averaged temperature evolution of all walls can be determined. In order, to complete the mathematical model the limit and initial conditions of the room must be known. Therefore, on each step the following temperature must be measured:

-The northern wall external face temperature.

- Ground temperature for a given depth (z).
- External temperature of the upper storey i.e. the temperature of the floor above. It is also necessary to measure the door and window temperatures since they are included in energetic balance.

Prior to establish this energetic balance the temperature profile of each surface of the two rooms has to be determined since it gives glance on directions and sense of heat exchanges with other surfaces. Preliminary remarks on dispositive (without insulation) dictate to decide and judge that:

Room 1:

$$T_{\text{Southern wall}} \langle T_{\text{Eastern wall}} \langle T_{\text{Ground}} \langle T_{air} \langle T_{\text{Ceiling}} \langle T_{\text{Western wall}} \langle T_{\text{Northern wall}} \tag{1}$$

Room 2:

$$T_{\text{Western wall}} \langle T_{\text{Southern wall}} \langle T_{\text{Ground}} \langle T_{air} \langle T_{\text{Ceiling}} \langle T_{\text{Eastern wall}} \langle T_{\text{Northern wall}} \tag{2}$$

The most important step in this current study consists in using a semi-empirical model allowing estimation of energy received by different walls to be made. In this sense, Capderou model has been chosen because it is the most adequate to the site where studies are carried out. (According to the previous studies). However, instead of implementing Capderou model to simulate the global and diffuse irradiation falling upon an horizontal plan, it was preferred in this work to use experimental results provided by a station located in the site where studies are carried out. This has a benefit of having more precise and better estimation of global irradiation on the vertical walls. For room 1, the two walls exposed to the sun are insulated by a lame of air of 4 cm and another layer of 6 cm of polystyrene. The western wall is insulated by 8 cm polystyrene layer. The roof is also insulated by 4 cm of polystyrene layer. Then in order to complete the insulation process, the northern wall was also insulated by 4 cm of polystyrene.

5. Numerical Simulation and Experimental Results

The experimental measurements are carried out in the first week of January 2009 and the first week of August 2009. The field specialized expert may ask why this choice is made. The answer is simple the choice is made on basis of walls energetic conditions. During this period the climatic and meteorological conditions are characterized by cold days more specifically over night and under shadow.

Figure 4, 5 represents the variations in temperature of interior air of the room without and with insulation. In summary, the orientation of the habitat for example to the West by 90◦, allows to make the south wall to West, West wall North, the North wall is and the wall is becomes in South

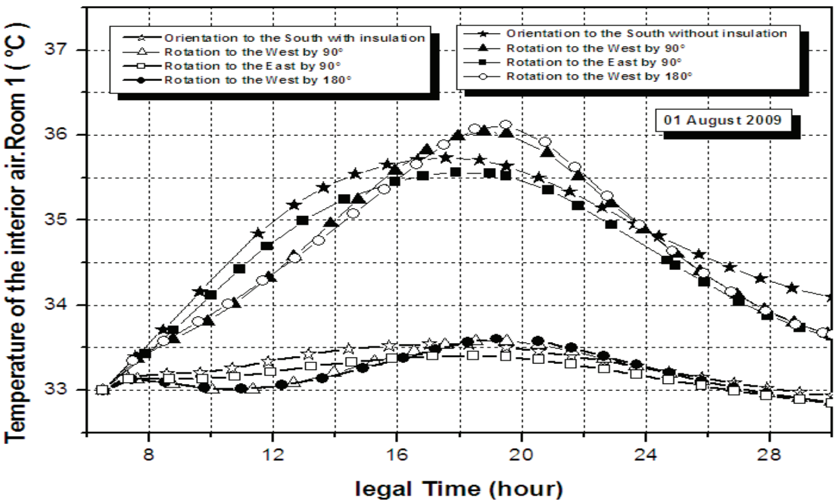

Fig4. Temperature of the interior air. Room 1 (Warm period)

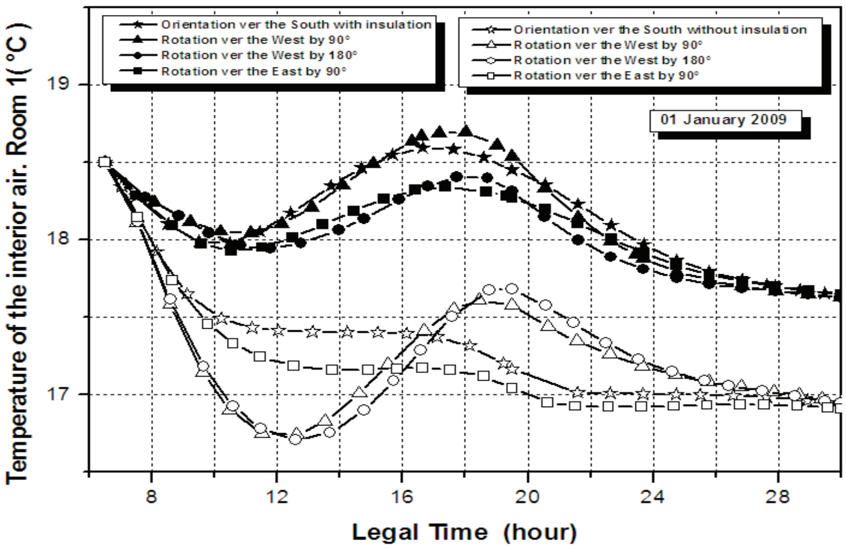

Fig5. Temperature of the interior air. Room 1 (Cold period)

6. Conclusion

The objective of this paper is to address the envelope impact on the interior temperature of a building in Saharan climates. In this work, we analyze features considered to have an impact on the building such as the building orientation, thermal inertia and thermal insulation. In the arid and semis-arid region, the problem of energy consumption is of great importance due to the air-conditioning cost. Several results have been obtained, we summarize them as follows:

- It is found that a proper insulation of the exposed walls in a building stone will not only increase comfort but also help in saving heating and cooling costs. Similar results have been found in previous studies, where it has been indicated in [4] that the insulation of exterior walls in warm as well as in cold season in China is the best strategy to decrease the energetic consumption.

- Measurements of temperature indicate that thermal inertia is the key property in controlling temperature oscillations. The correct use and application of thermal mass depends on the prevailing climate. The thermal insulation in this case is insufficient due to the fact that several walls are exposed to the sun radiations. In addition to that, stones are an ideal material for thermal mass (with high specific heat capacity and high density). In other words, in hot season of Saharan climates, the use of high thermal inertia walls in buildings can not avoid outdoor heat to come indoor during 24 hours. We can retain that the walls thermal inertia in these situations, play a contradictory role because the nights are not fresh. So even in the presence of a high thermal inertia, reduction of energy consumption in buildings is a major aim and is a particular challenge in desert climate.

- For the region of Ghardaïa, it has been found that changing orientations of building is not beneficial in term of thermal comfort particularly in the hot season because they conduce to overheating. The influence of orientation changing depends on the floors and exterior walls constructing materials, the insulation levels and application of the inseparable rules of the bioclimatic design.

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